



Aerodynamics and Autonomous Soaring

Stephen Cumming

Michael Allen

NASA Dryden Flight Research Center

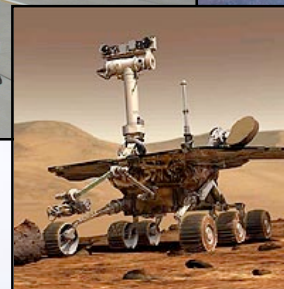
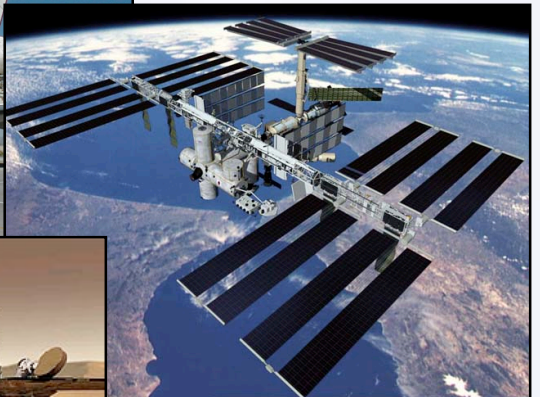
2005 Math & Science Odyssey

Antelope Valley College

About NASA



- National Aeronautics and Space Administration
- Aeronautics
 - Jet airplanes
 - Helicopters
 - Autonomous airplanes
- Space
 - Space shuttle
 - Space station
 - Mars rovers





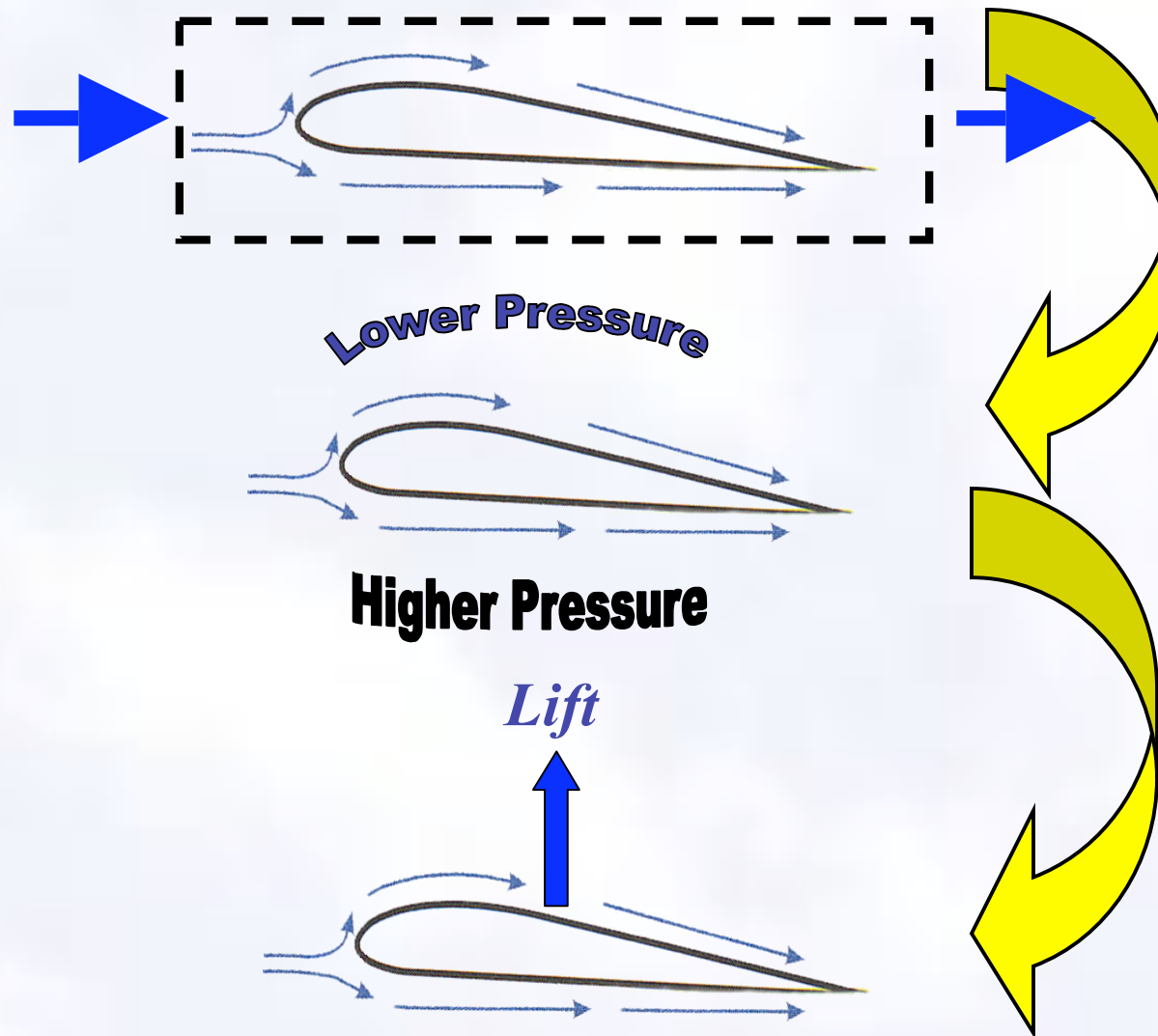
Aerodynamics: The Mysteries of Flight



Outline

- Basics of Flight...How Flight Works
- Flight Systems
- Controlling Flight

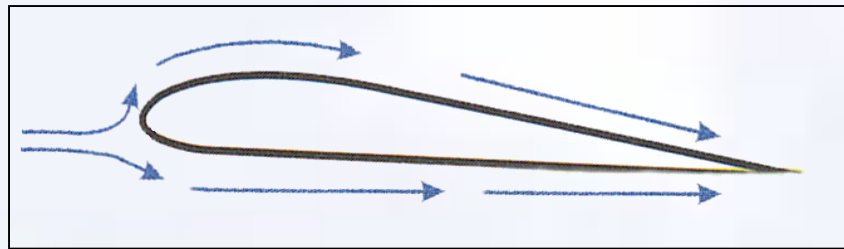
Bernoulli's Principle





Airfoil: The Blueprint for Lift

The shape of the wing is called the airfoil.



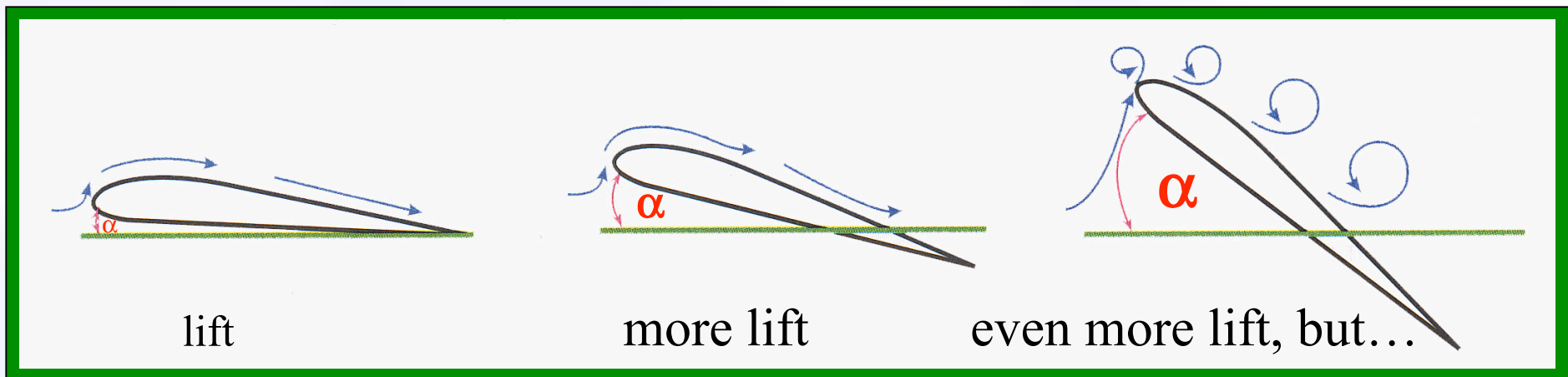
A wing can produce more lift by

- increasing velocity (by speeding up)
- increasing angle-of-attack (by 'pitching up')
- changing the shape of the wing (with control surfaces)



Angle-Of-Attack: Quick Lift

Lift can also be increased by increasing the airplane's ***angle-of-attack*** (α) ...

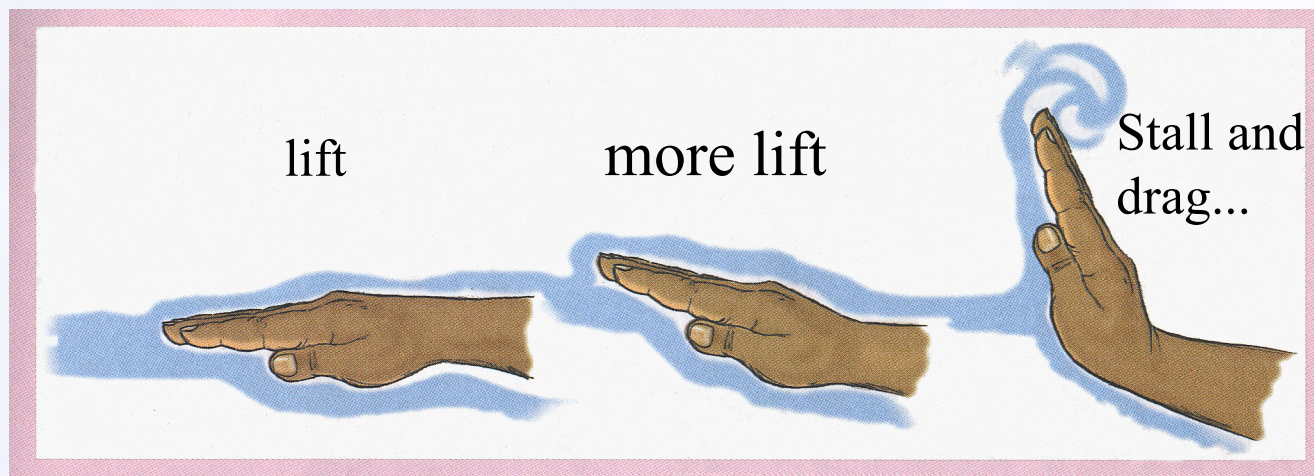


Too much α results in ***stall***, or loss of lift...
Stall also results in a LOT of drag...

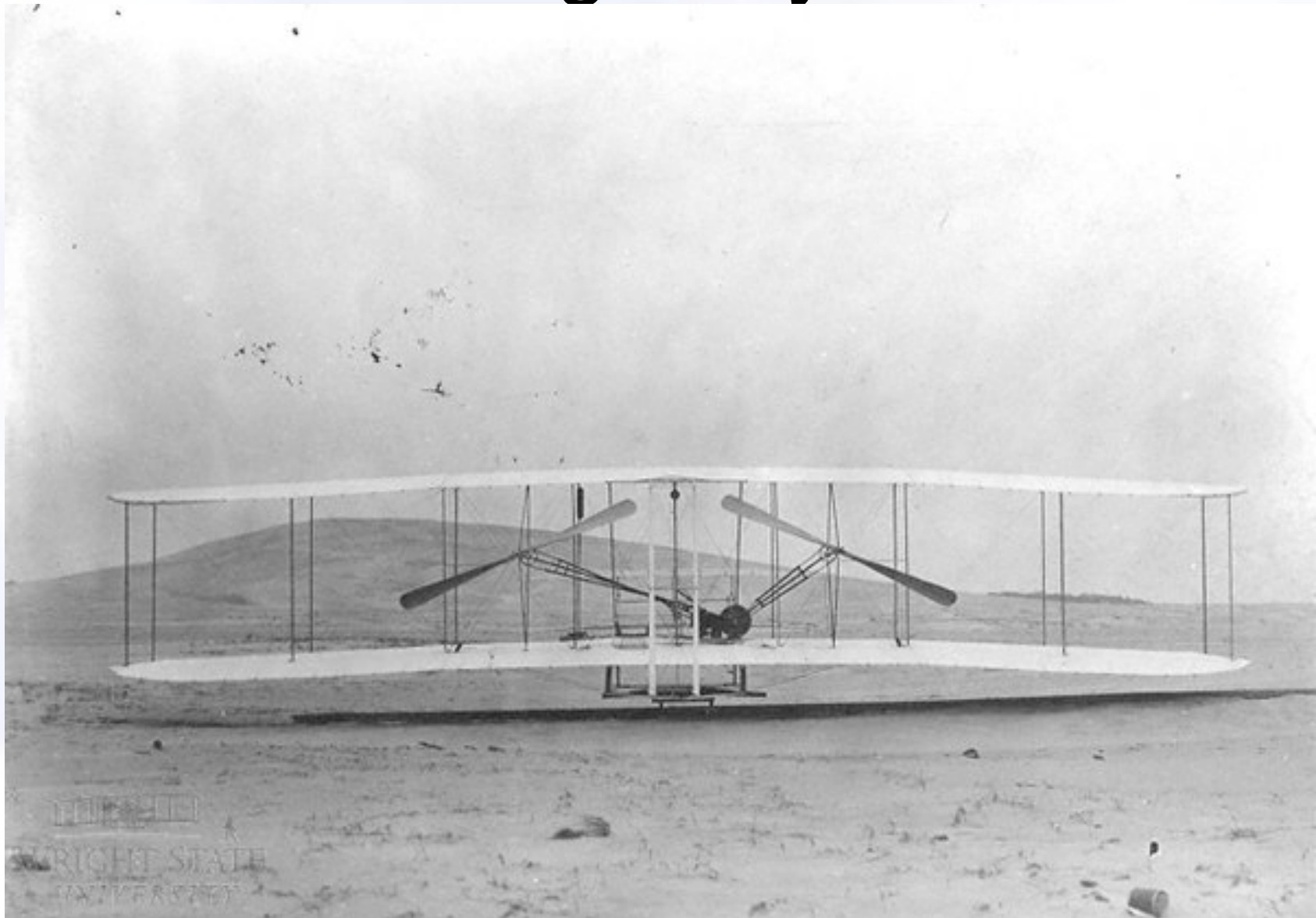


Angle-Of-Attack: Do-It-Yourself

Next time you're in the car, stick your hand outside the window...



Wright Flyer



Wright Flyer



Wright Flyer



Discovery Channel's Recreation of the First Flight

http://exn.ca/flight/wright_brothers/flights/default.asp

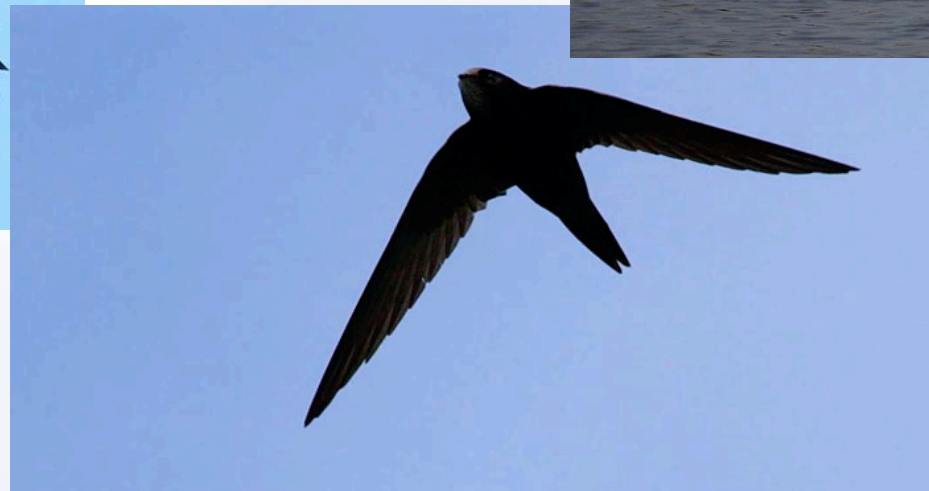
F/A-18



F/A-18



Biological Flight Systems... Birds!

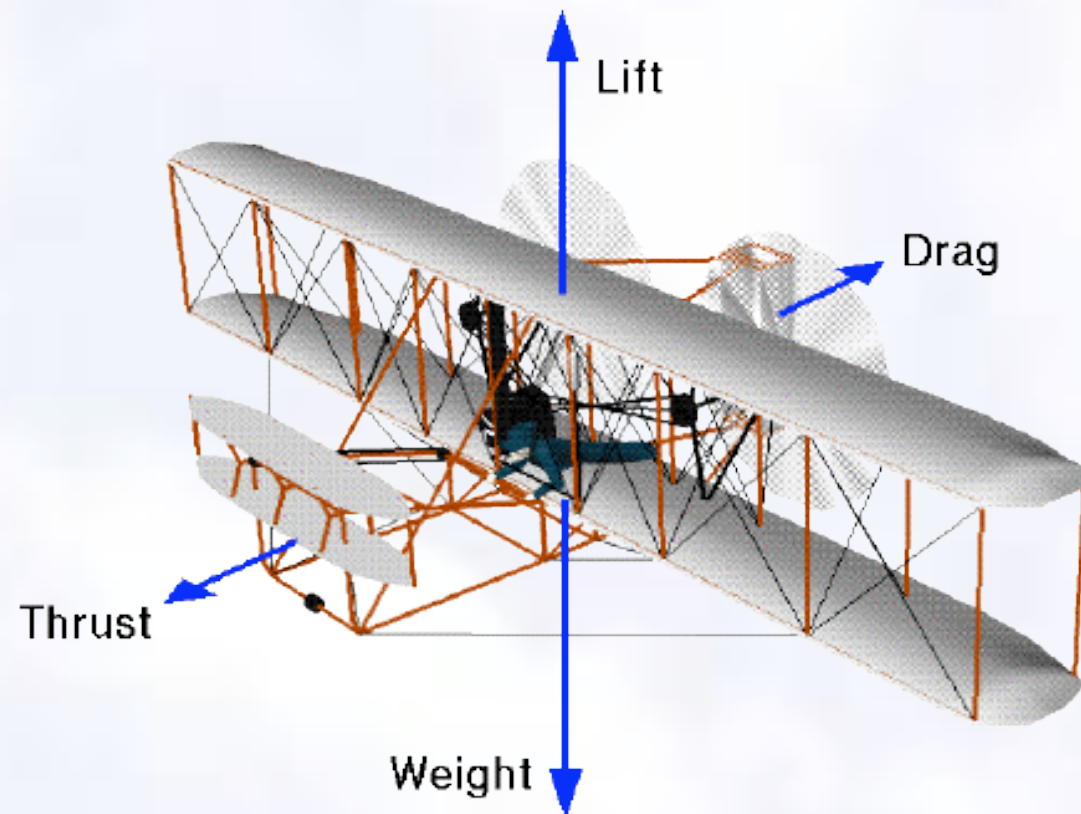


Control



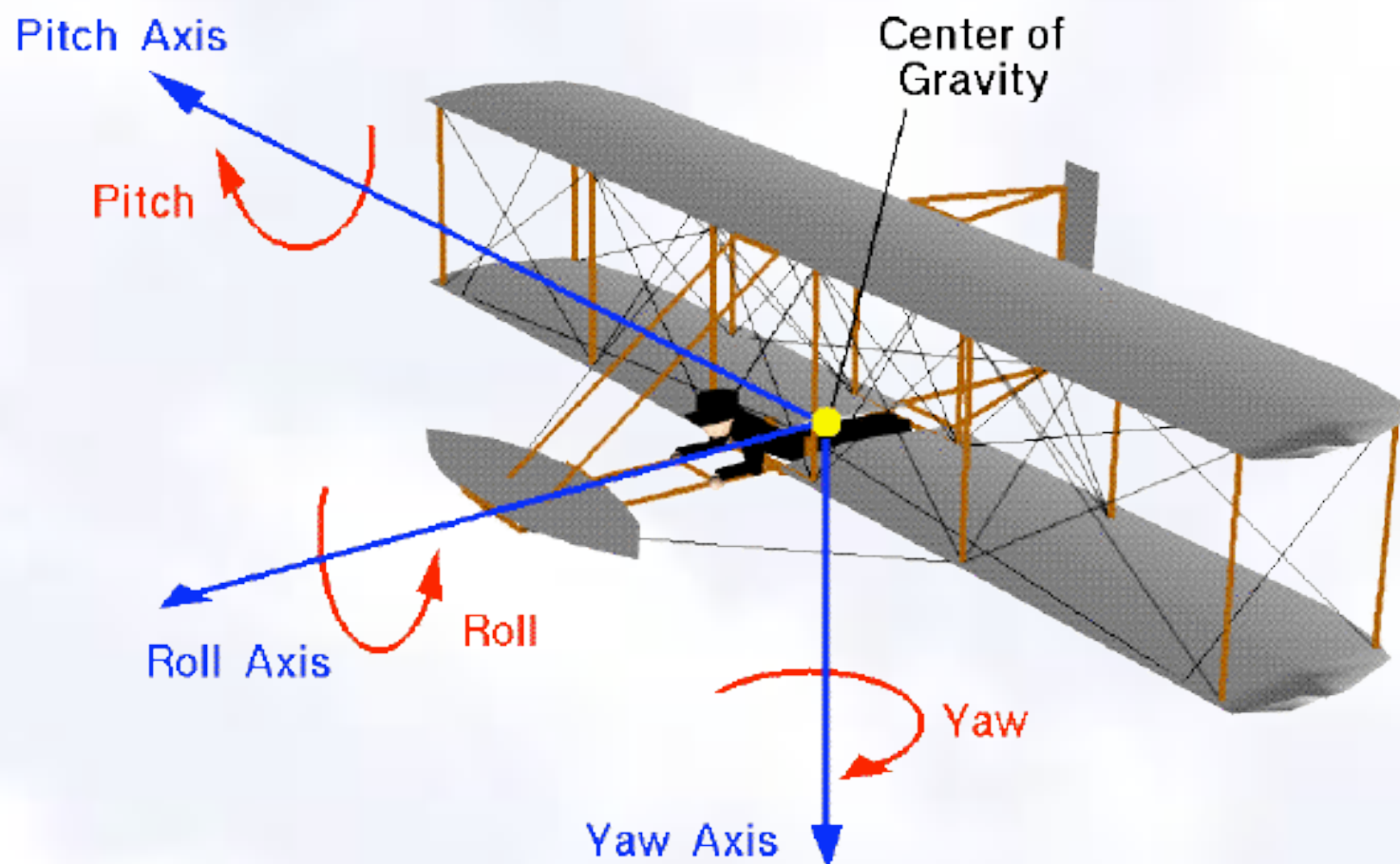
- Need to balance forces
- Want to get where you're going!

Aircraft Forces

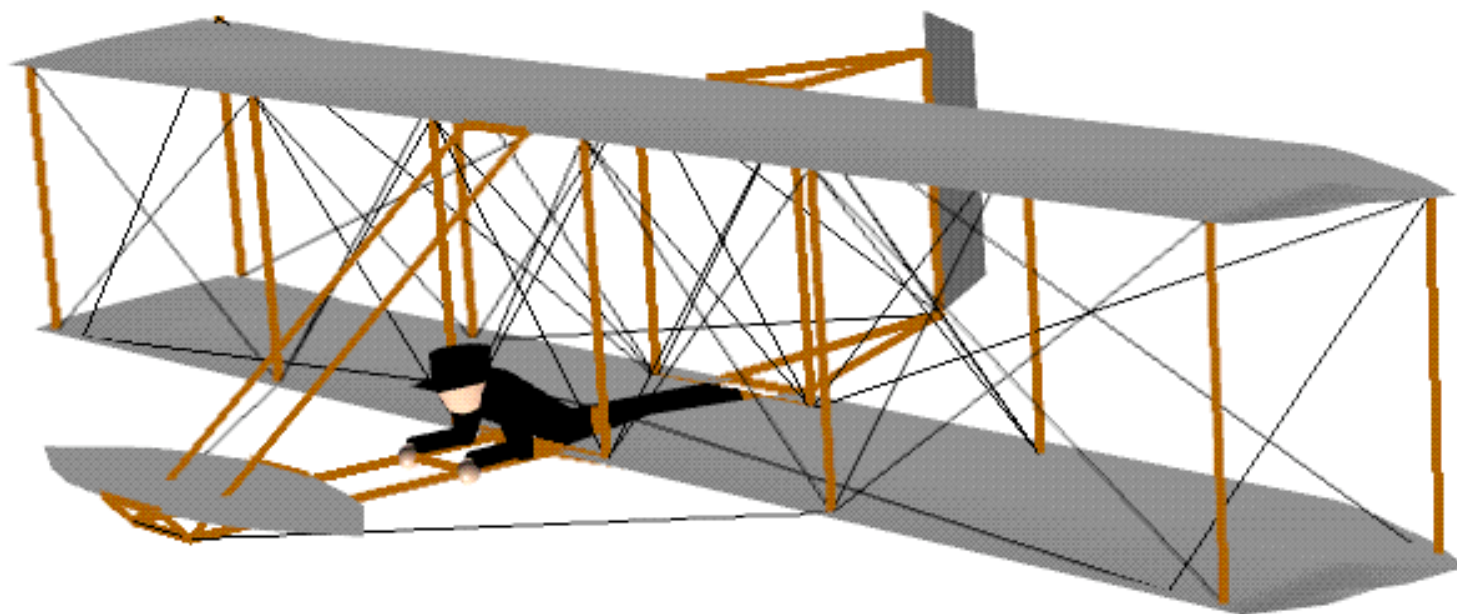




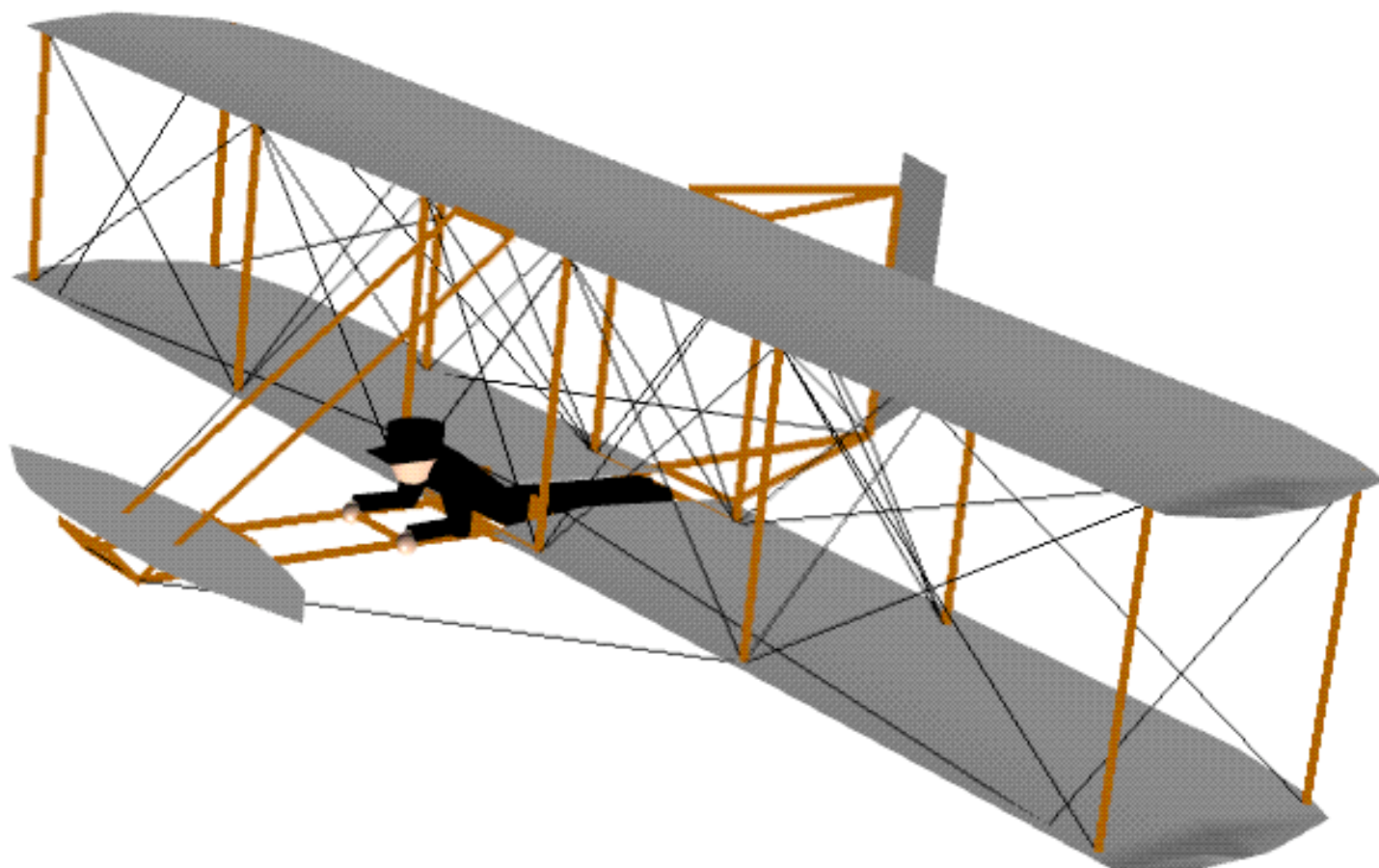
Aircraft Axes



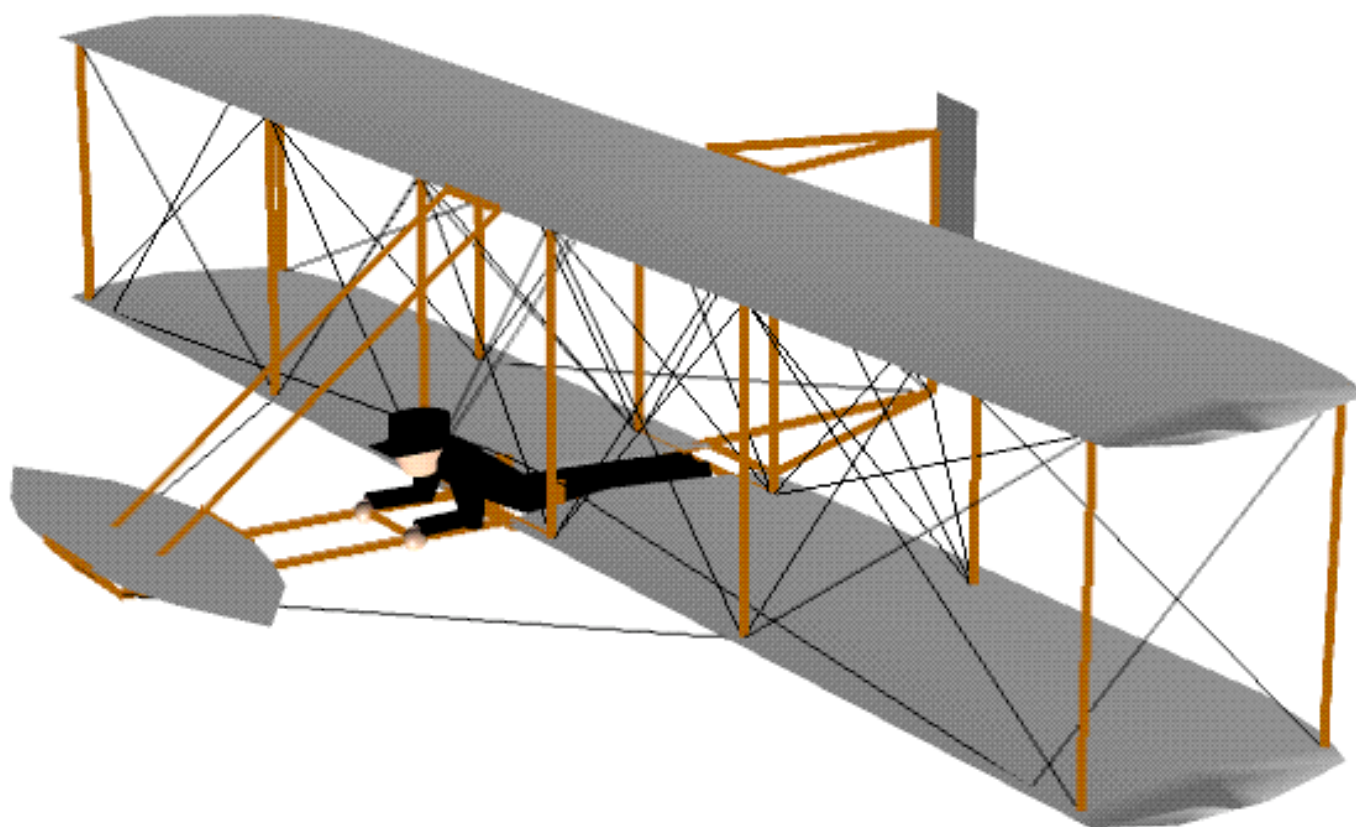
Roll



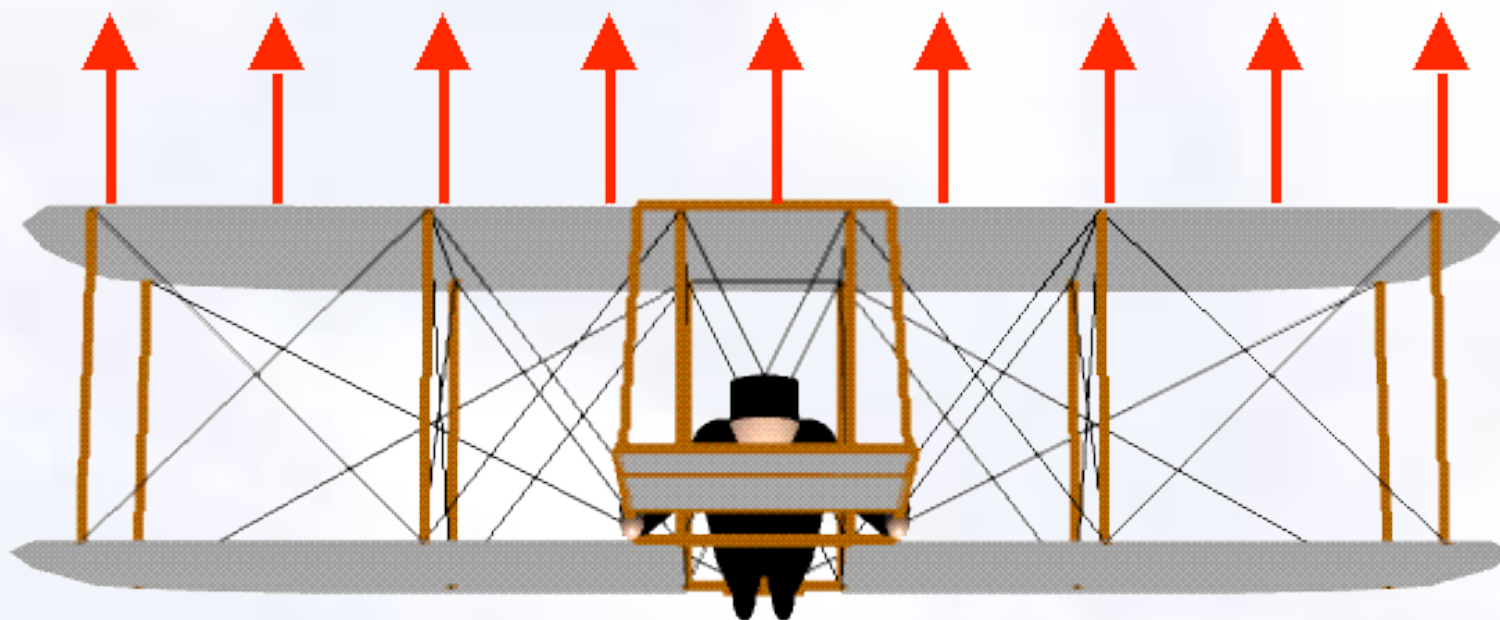
Pitch



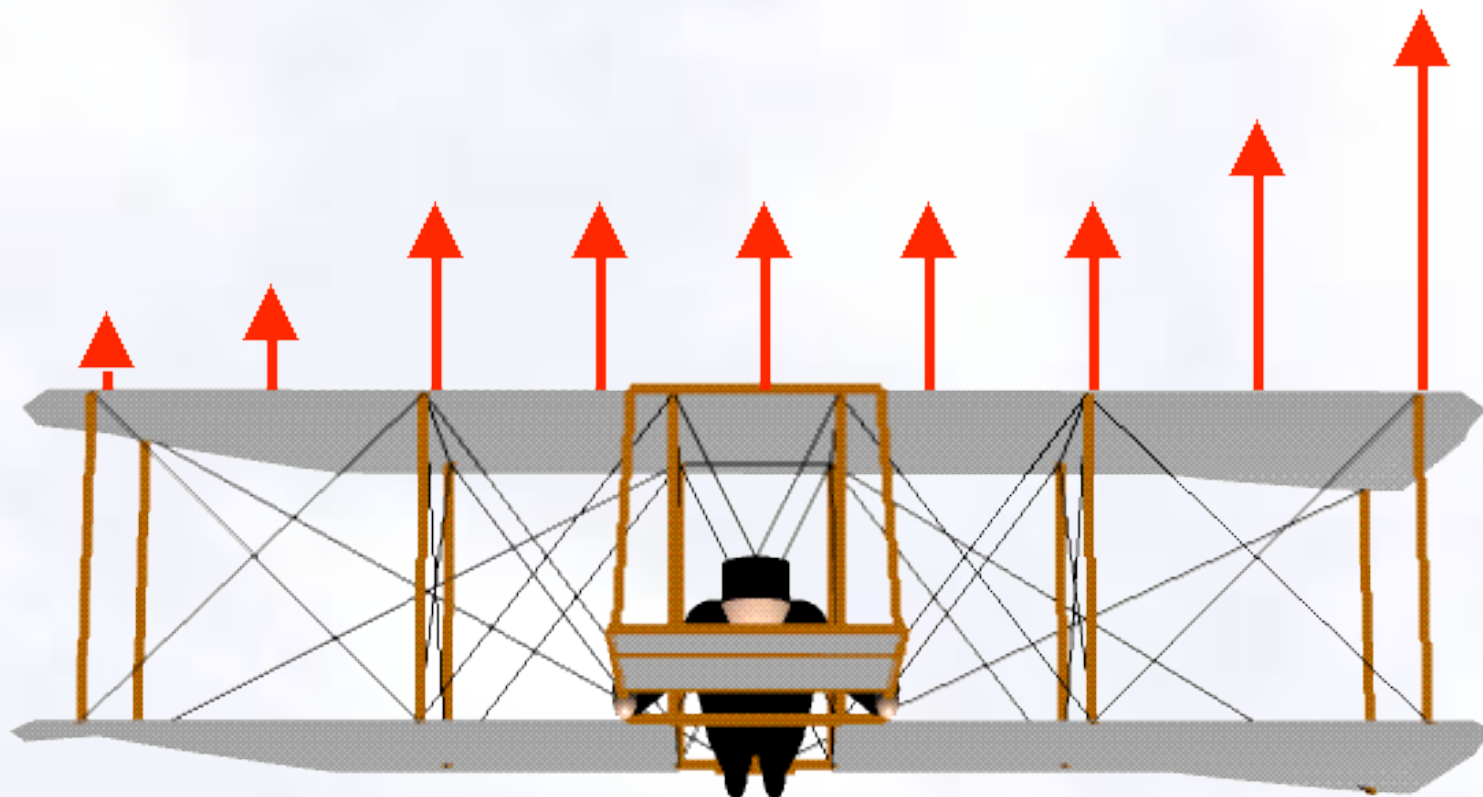
Yaw



Wing Warping



Wing Warping



Controlling the Airplane – ROLL

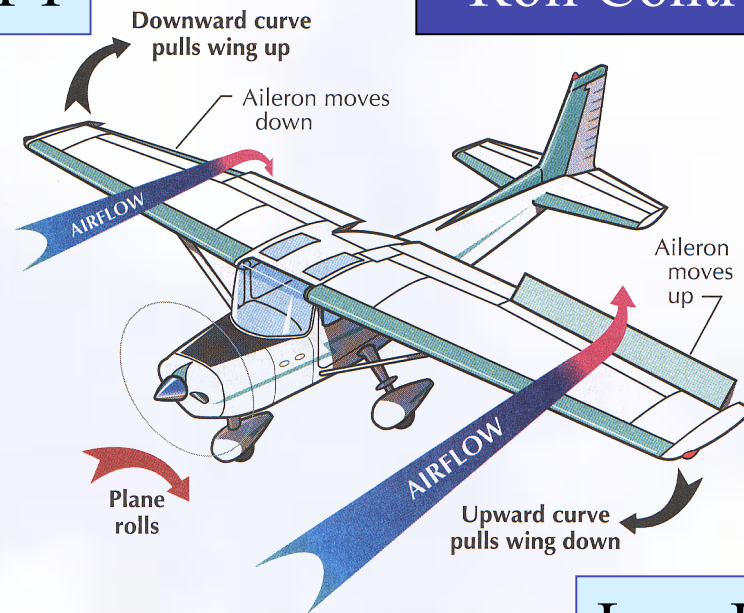


To make the airplane **ROLL** to one side, you **INCREASE** the **LIFT** on one side of the wing using **ailerons**...

With more lift on one wing, and less on the other, the aircraft **ROLLS** towards the weaker side...

More LIFT

Roll Control



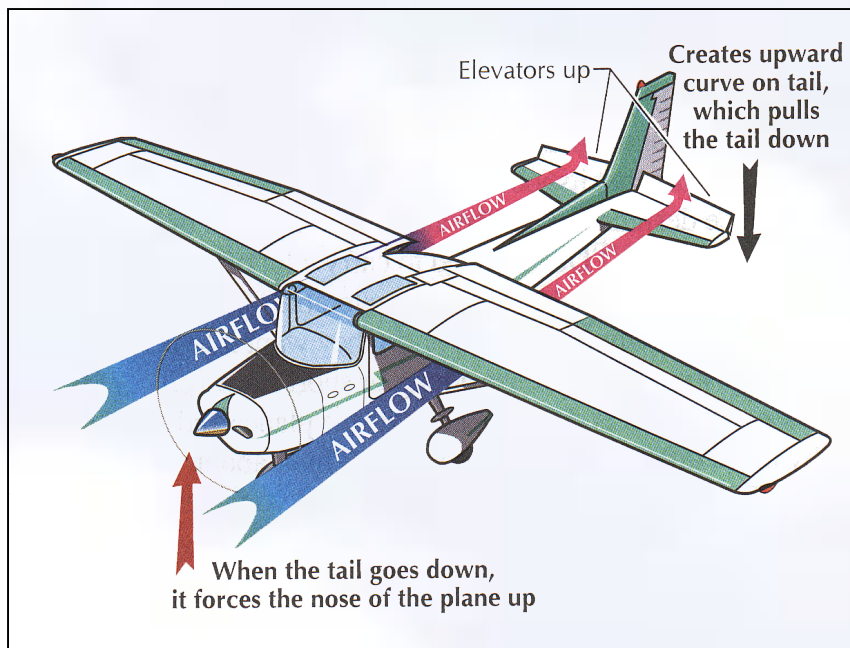
Less LIFT

Controlling the Airplane



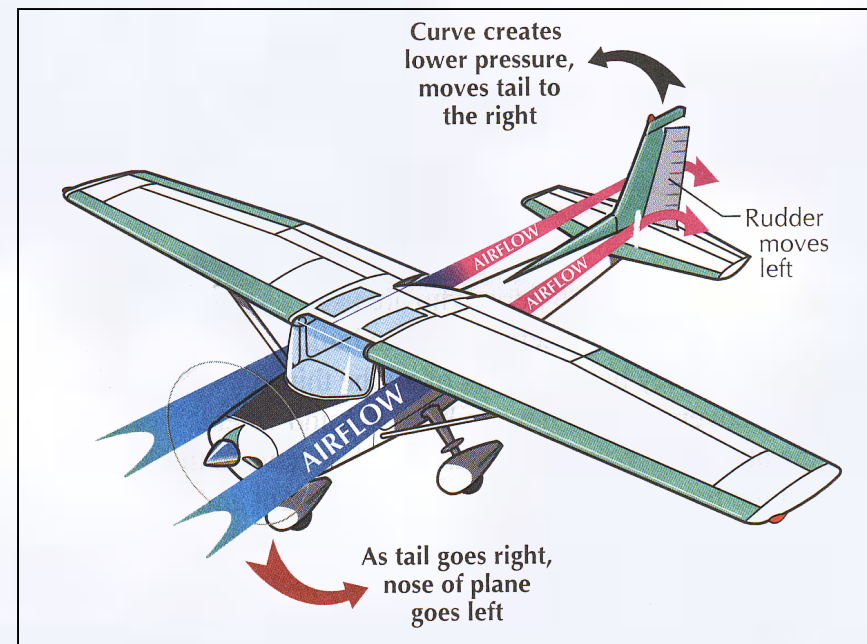
Pitch Control

The **elevators** control the **lift** on the **horizontal tail**, and make the nose go **up and down**...



Yaw Control

The **rudders** control the **lift** on the **vertical tail**, and make the nose go **left and right**...



Active Aeroelastic Wing



- F/A-18 with more flexible wings
- Control surface deflection creates wing twist
- This is similar to wing warping!

Avian Flight Controls



Tilly the Eagle

Discovery Channel's Animal Planet

<http://animal.discovery.com/convergence/spyonthewild/birdtech/birdtech.html>

More Info...



- “Wild Blue Wonders: Exploring the Magic of Flight,” by Lane Wallace. EAA, 2001.
- “A History of Aerodynamics,” by John D. Anderson, Jr. Cambridge University Press, 1997.
- “Illustrated Guide to Aerodynamics,” by H.C. Smith. The McGraw-Hill Companies, 1991.
- <http://www.first-to-fly.com/>
- <http://www.nasa.gov/>
- <http://wright.nasa.gov/>

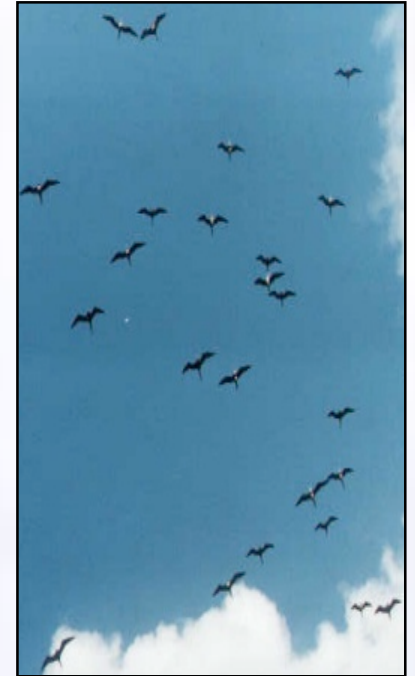
Autonomous Soaring



How to Make an Airplane Soar



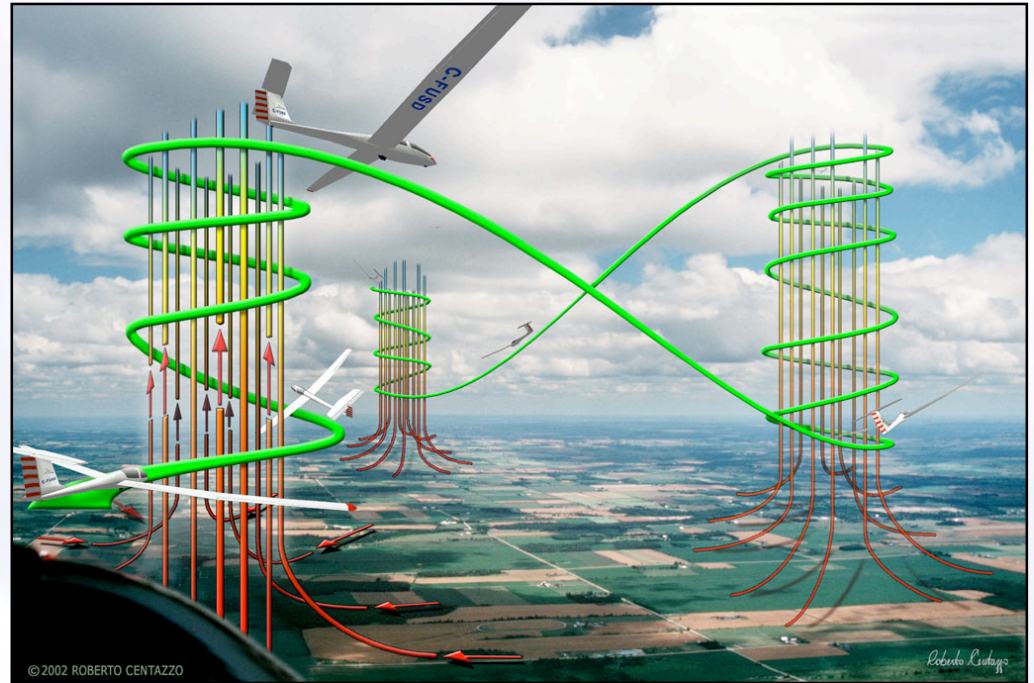
- Soaring is when a bird or glider uses wind currents to stay up.
- Birds like to soar because they don't have to flap their wings all the time.
- At NASA we decided to see if a computerized airplane could also soar.





Updrafts

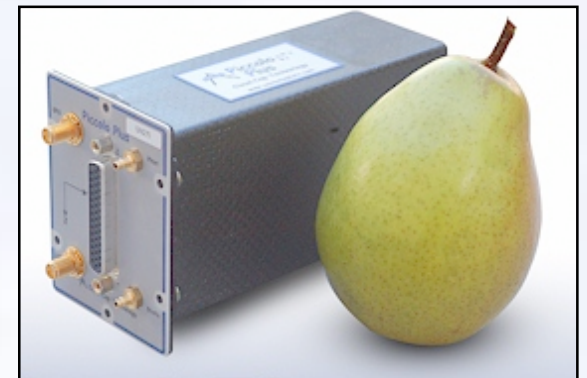
- Updrafts form when the sun heats the ground
- The warm ground makes the air near the ground hotter than the air above it.
- Hot air rises.
- If an airplane or bird stays in the rising air it will rise



Research Airplane



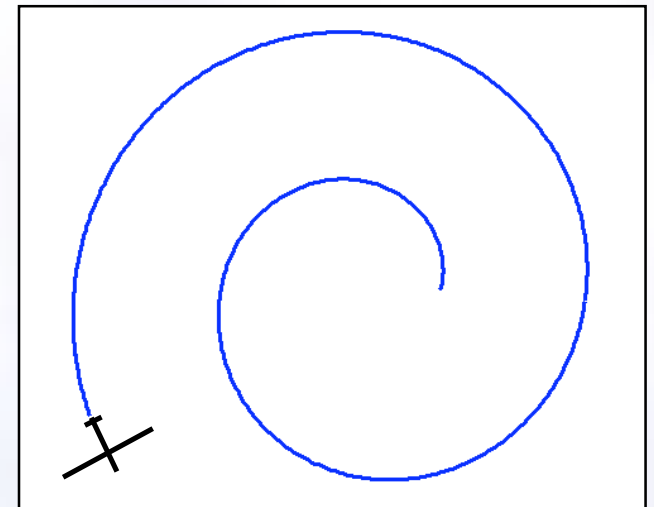
- CloudSwift Aircraft
 - Span: 4.26m (14ft)
 - Weight: 6.58kg (14.5lb)
 - Stall speed: 18kt
 - Mission speed: 25kt
- Piccolo Autopilot
 - Weight: 212g (7.5 oz)
 - Sensors:
 - Rate gyros
 - Accelerations
 - Static & total pressure
 - GPS position & velocity
 - Custom software developed for this project



Search Path



- The airplane did not know where the updrafts were.
- Archimedes spiral pattern was chosen for the airplane to fly while searching for updrafts.

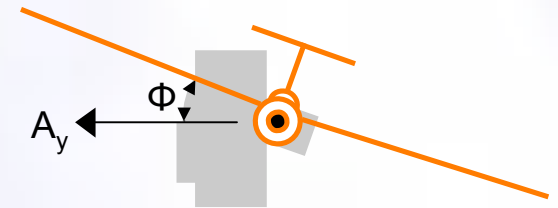


$$r = a * \psi + b$$

Soaring UAV Simulation Study,

Climb Performance

- A flight simulator was used to predict if the airplane would soar or not.
- Equations were used to calculate the forces and moments on the airplane.



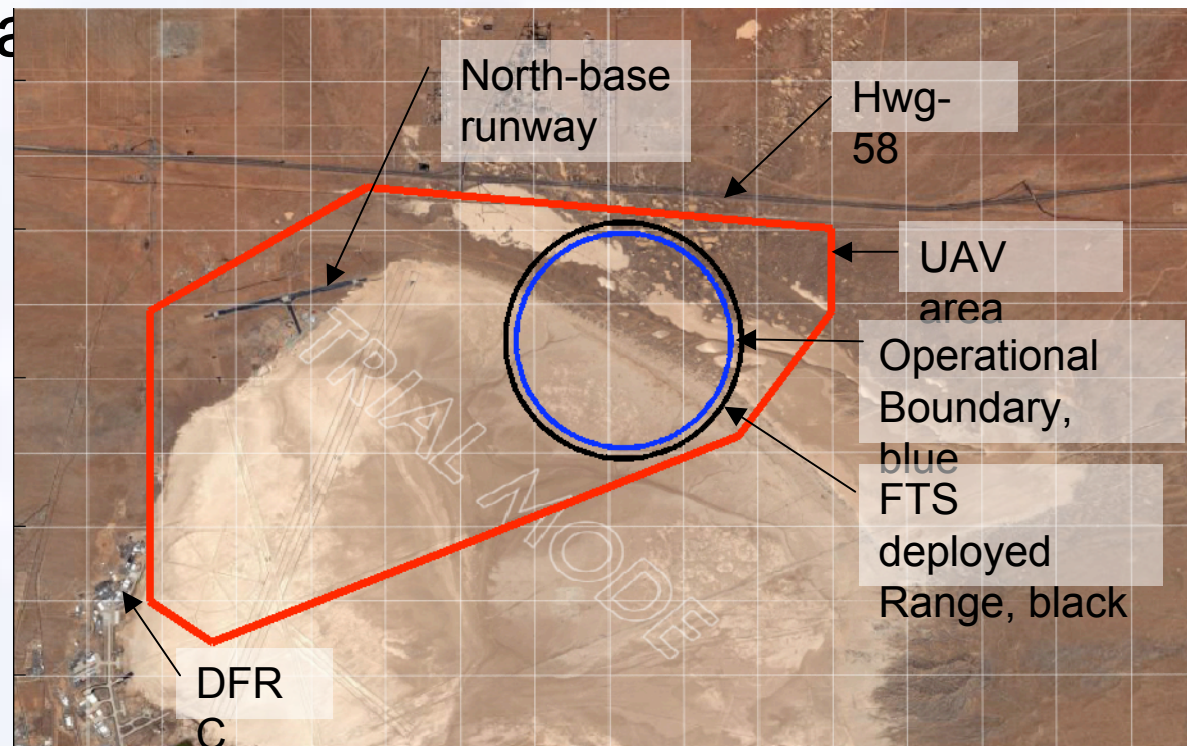
$$N_z = \frac{1}{\cos(\phi)}$$

$$S_i = \frac{V * (1 + N_z^2)}{2 * \frac{L}{D}}$$

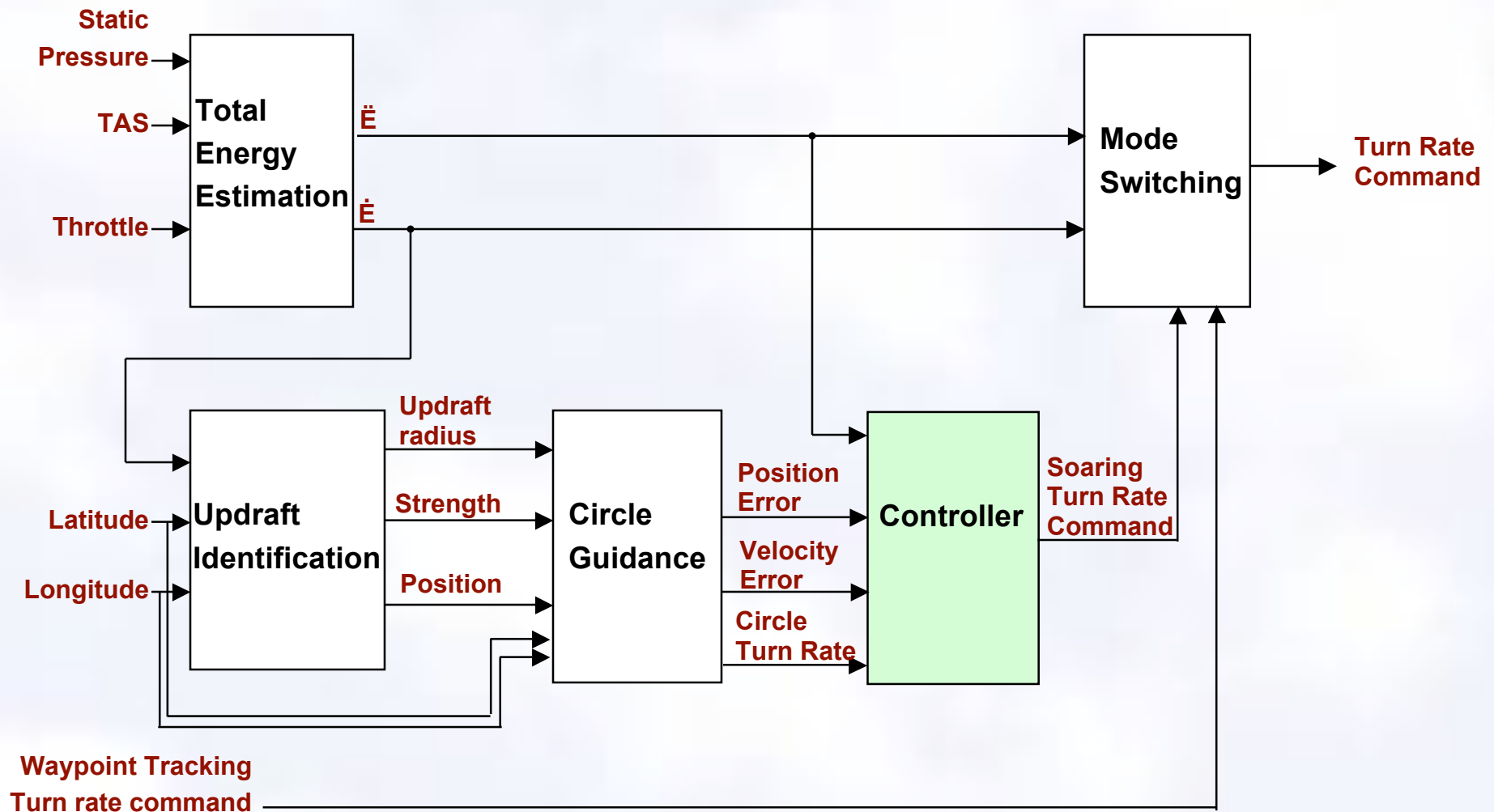


Flight Test Plan

- Safety bounds were used to make sure that the airplane didn't fly over to highway 58 and hit a car



Algorithms for Soaring



Flight Test Results



- 17 flights were conducted
 - perform aircraft checkout
 - autopilot gain tuning
 - FTS range tests
 - research flights
- 23 updrafts were found.
- Average climb for all updrafts = 172m (567ft)

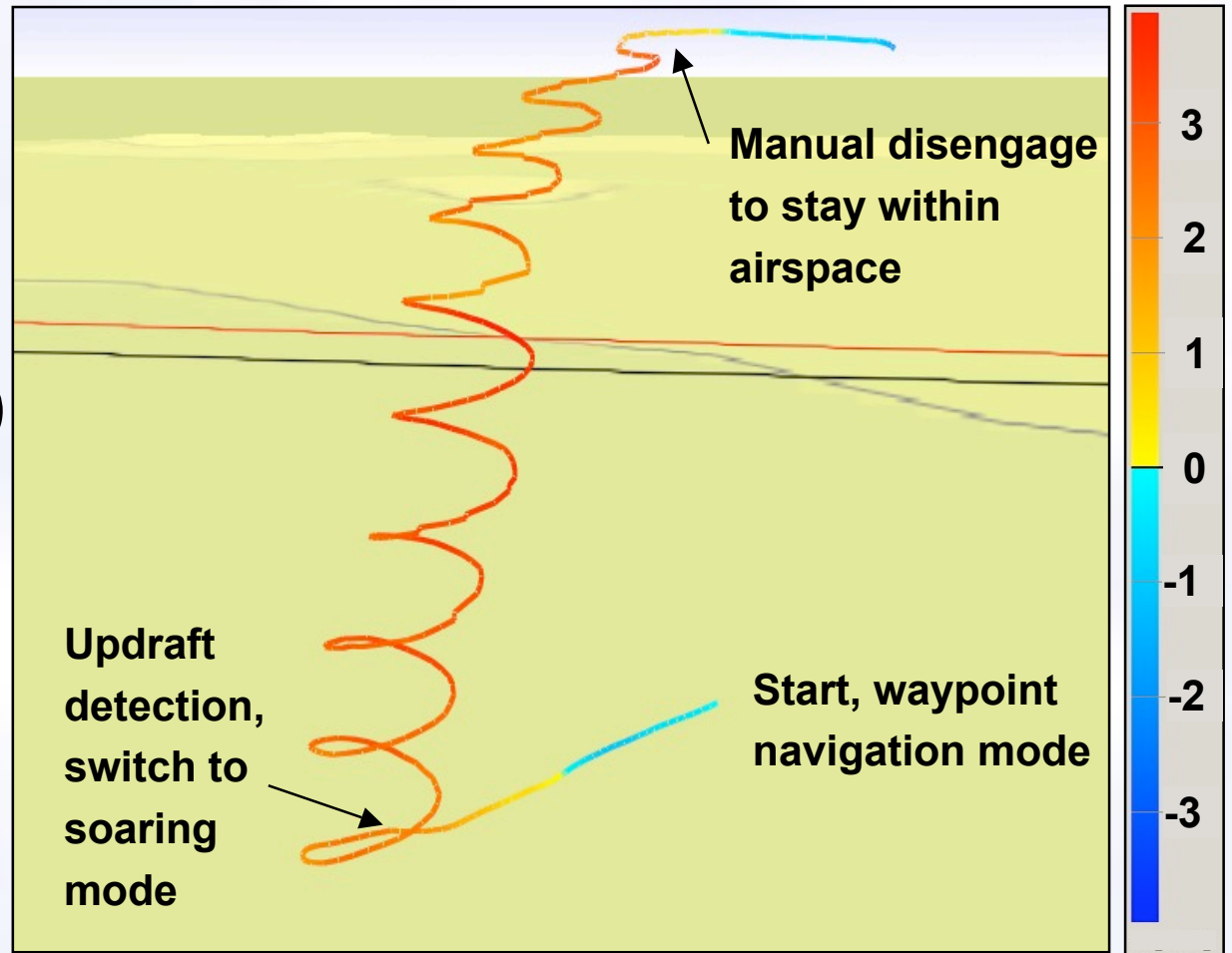


Flight Test Results



Flight 12, Updraft 2

- Highest climb in a single updraft
- Sept 9, 2005.
- 844m (2770ft) altitude gain.



Climb-
rate, m/s

- **Play:**
cloudSwift_flt12_up2.i
ac



Questions?